VISUALISING AND MAPPING A HALF CENTURY OF LITERATURE ON COMPUTER SCIENCE EDUCATION RESEARCH

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Abstract: Over the last few decades, research on computer science education has accelerated, amassing more data about the importance of the subject in computing education. As such, a bibliometric analysis was done on computer science education research between 1970 and 2021 to determine how frequent this type of research is published. The study found 800 relevant papers for further research based on the keywords in the title of the article, which is related to computer science education. Data from publication network were used to produce maps that demonstrate how researchers, countries, and journals are linked together. The co-occurrence of several terms associated with computer science education research was investigated using author keywords. The results show a significant and robust connection between the top authors, implying a substantial and robust research connection. The United States was the top country researching computer science education, while ACM SIGCSE Bulletin had the most articles. The most frequently used author keywords were "computer science education," "computer science," "education," "curriculum," "computational thinking," "k-12," "cs1," "gender," "diversity," and "game-based learning". These analyses of current work serve as a valuable and significant resource for academics and policymakers in computer science education research.

Keywords: Computer Science Education, Bibliometric Analysis, Scopus, VOSviewer

INTRODUCTION

In recent years, computer science has gained popularity as a field that examines the initial growth of computing education research. Traditional educational institutions organise and plan computer science courses (Gubina et al., 2020), where computer science education will become a major educational aim (Mirzoev et al., 2021; Tissenbaum & Ottenbreit-Leftwich, 2020). Concurrently, numerous student-focused topics, such as making computer science more appropriate from a gender, diversity, accessibility, and inclusion standpoint, have recently gained substantial attention (Repenning et al., 2020; Spieler et al., 2020). Computer Science Education (CSE) will be the future curriculum trend, as this study focuses on the state of computer science research and development in education as well as deep integration of computer science education.

The necessity to designate an appropriate discipline of computer science as a curriculum subject was a significant factor. The first curriculum focused CSE study was published in 2004 and continues to grow. However, recent CSE research efforts should be evaluated using bibliometric analysis. Furthermore, researchers in the subject have differing perspectives on the field's scope, which might be addressed in future student teaching. The previous study agrees that computer science is a diverse field with scientific and technical components (Burbaite et al., 2018; Schulz & Pinkwart, 2016), algorithmic problem-solving components (Wing, 2006), and occasionally, artistic and creative components (Burbaite et al., 2018). A consensus exists about conceptual ideas, with the computer as a tool for solving computer science problems (Clua et al., 2006).

Computer science education varies in different nations, where Israel, Cyprus, and Poland have had computer science for many years (Doukakis & Papalaskari, 2019). Meanwhile, others have just changed their computer science curriculum following years of neglect and requests for reform (Hazzan et al., 2020). The approach and importance of many aspects that affect curriculum design and implementation vary among nations where computer science is taught.

In 1989, the Twentieth SIGCSE Technical Symposium on Computer Science Education article of the ACM SIGCSE Bulletin explored the nature of computer science. From a pedagogical perspective, diverse bodies and

countries' interpretation of high school computer science curricula indicates a lack of standardisation (Swacha et al., 2021). Computer science, informatics, computer engineering, and software engineering are just a few curricula names that reflect the many methods (Resnyansky et al., 2019). Diverse high school curricula reflect different approaches. It is noteworthy that early computer science education has influenced students' perceptions of the profession (Samarasekara, 2020). The relevance of other computing and computer use areas, such as digital literacy, was also recognised, which can be integrated into a computer science curriculum. This study utilized (i) the Scopus database for bibliometric assessment and (ii) mapping to holistically comprehend worldwide CSE research patterns.

The following research questions (RQ) were address in this study:

RQ1: What are the volume, growth of publications, collaboration, and geographical distribution of publications on CSE?

RQ2: Which journals have emerged as thought preferred in the CSE literature?

RQ3: What are the topical trends of scholarship on CSE?

METHODOLOGY

Bibliometric Analysis

Pritchard (1969) defines bibliometrics as "applying mathematics and statistical methodologies to books and other communication media". Based on bibliographic data, the bibliometric analysis examines the qualities of books (in this example, a collection of literature). A bibliometric analysis is becoming increasingly popular for revealing study trends and patterns (Mansour et al., 2021). The publication patterns can be observed by year, author, affiliation, or country. The publication's influence and performance can be evaluated using matrices such as citations, citations per year, h-index, and g-index. The state-of-the-art articles can also be mapped and visualised using markers, such as co-authorship, co-citation, keyword occurrences, and bibliographic coupling. It is believed that the increased use of bibliometric analysis is attributable to the ease of downloading data from academic databases (e.g., Web of Science, Scopus and Dimensions) and the availability of tools (e.g., VOSviewer, CiteSpace and CitNetExplorer).

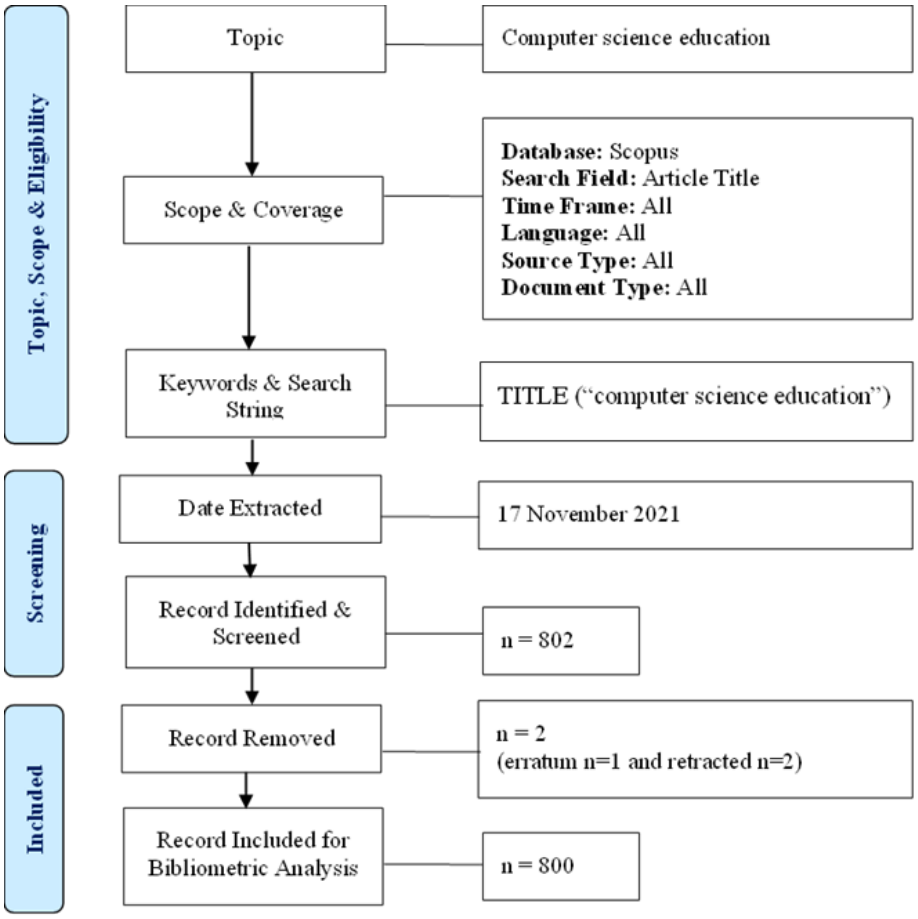

Figure 1: Flow Diagram of the Search Strategy

Data Collection

The Scopus database was searched on 17 November 2021. The Scopus index was used as the data repository. In comparison to Web of Science, Scopus covers more sources than Web of Science in non-medical and non-physical disciplines (Swacha et al., 2021). Scopus currently has over 800 source titles from over 160 publishers. The article's title was used to search for "computer science education" (CSE) trends. The search dates from 1970 to 2021 are considered to determine how often CSE research is published. Erratum and withdrawn document categories were eliminated to avoid double counting. Figure 1 depicts the search strategy flow diagram. The retrieved data were used to create a graph depicting the rise in publishing and total citations of scholarly articles published in the field of CSE between 1970 and 2021. The software VOSviewer (version 1.6.15) was used to visualise bibliometric networks. The networks were visualised as a map, with colour, circle size, and line thickness representing cluster or group membership, production or citations, and close connection (collaboration) strength (Ariza & Baez, 2021). Furthermore, co-occurrence analysis was adopted to construct maps of: (1) co-authorship among authors, countries, and journals; and (2) author keyword co-occurrence.

RESULTS AND DISCUSSION

This section shows the results of a bibliometric analysis of 800 publications with the title CSE published between 1970 till 2021.

Growth of publications

The Scopus database search resulted 800 items from 1970 to 2021. Figure 2 shows the total citations of research works on computer science education from 1970 to 2021. The publication growth pattern over time is analysed by looking at the documents by year (Zakaria et al., 2021). From 1970 to 2003, there was a slow but continuous rise

in interest in computer science education, with 26 documents published in 2004. The increase in publications after 2004 coincides to several countries introducing computer science education into the curriculum.

The submissions from 70 countries show that scholars are interested in computer science education. Table 1 covers the top 10 publishing countries on computer science education with at least 14 articles, with the top three being the United States, Germany, and the United Kingdom. More than 368 articles were found in 21 sources titles. Table 2 shows the most prominent source's title on computer science education: the ACM SIGCSE Bulletin, the Annual Conference on Innovation and Technology in Computer Science Education (ITiCSE), and the SIGCSE Bulletin Association for Computing Machinery Special Interest Group Computer Science Education, and the Lecture Notes in Computer Science.

Based on the dataset in this work, 159 authors from 157 organisations published articles on computer science education. Table 3 includes the top contributing scholars and organisations. According to the abovementioned table, Hazzan, O authored 13 articles on computer science education, followed by Zendler, A with 11 and Hubwieser, P with 10. The University of Texas at Austin contributed 15 articles, followed by the Georgia Institute of Technology and the Israel Institute of Technology. The majority of scholars and organisations are from the United States and Israel. However, many research used samples were from the United Kingdom and Asia. While most research on computer science education is done in the West, contributions were made worldwide.

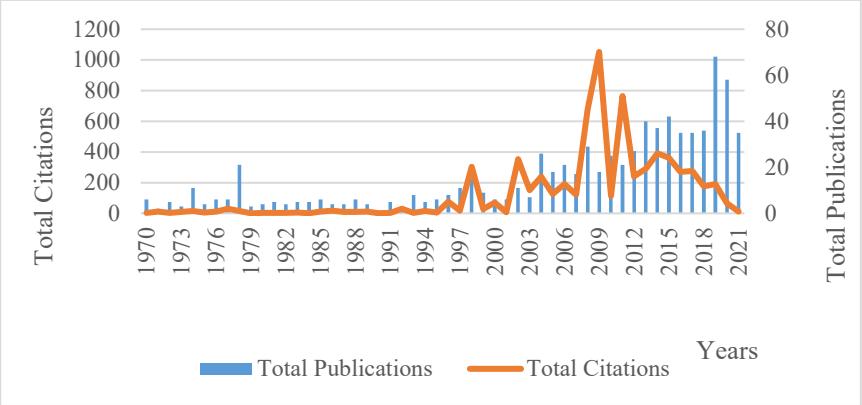

Figure 2: *Annual distribution of articles on computer science education retrieved from Scopus. This figure presents the number of articles on computer science education annually taken from the Scopus between 1970 and 2021.*

Table 1
Top publishing countries on computer science education.

Country	Documents	Citations	Total Link Strength
United States	343	3739	57
Germany	83	844	15
United Kingdom	45	412	24
Israel	30	565	8
Finland	24	470	11
Australia	22	257	12
Austria	18	250	6
Canada	18	67	7
China	18	101	4
Norway	14	311	10

[a] This table shows the top 10 publishing countries on computer science education

Table 2
Most active sources title on computer science education

Sources Title	SJR 2020	Publisher	Number of Articles
ACM SIGCSE Bulletin	NA	Association for Computing Machinery, Special Interest Group on Computer Science Education	53

Sources Title	SJR 2020	Publisher	Number of Articles
Annual Conference on Innovation and Technology In Computer Science Education (ITiCSE)	NA	Annual Conference On Innovation and Technology In Computer Science Education (ITiCSE)	42
SIGCSE Bulletin Association For Computing Machinery Special Interest Group On Computer Science Education	NA	Association for Computing Machinery, Special Interest Group on Computer Science Education	34
Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence and Lecture Notes In Bioinformatics	0.249	Springer Nature	30
ACM International Conference Proceeding Series	0.182	ACM International Conference Proceeding Series	29
Proceedings of The Conference On Integrating Technology Into Computer Science Education (ITiCSE)	NA	Proceedings of The Conference On Integrating Technology Into Computer Science Education (ITiCSE)	28
Computer Science Education	0.83	Taylor & Francis	20
Communications of The ACM	0.967	ACM	19
Proceedings Frontiers In Education Conference Fie	0.194	Proceedings - Frontiers in Education Conference, FIE	15
ACM Inroads	0.194	ACM	11
Proceedings Frontiers In Education Conference	0.194	Proceedings - Frontiers in Education Conference, FIE	11
ACM Transactions On Computing Education	0.837	ACM	10
PervasiveHealth Pervasive Computing Technologies for Healthcare	NA	PervasiveHealth Pervasive Computing Technologies For Healthcare	9
IEEE Global Engineering Education Conference EDUCON	NA	IEEE Global Engineering Education Conference EDUCON	8
Lecture Notes In Informatics Lni Proceedings Series of The Gesellschaft Fur Informatik Gi	0.148	Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft fur Informatik (GI)	8
SIGCSE 2021 Proceedings of The 52nd ACM Technical Symposium On Computer Science Education	NA	SIGCSE 2021 Proceedings of The 52nd ACM Technical Symposium On Computer Science Education	8
ASEE Annual Conference and Exposition Conference Proceedings	NA	ASEE Annual Conference and Exposition Conference Proceedings	7
Computer	0.846	IEEE	7
SIGCSE 10 Proceedings of The 41st ACM Technical Symposium On Computer Science Education	NA	SIGCSE 10 Proceedings of The 41st ACM Technical Symposium On Computer Science Education	7
Ceur Workshop Proceedings	0.177	CEUR Workshop Proceedings	6
Education and Information Technologies	0.919	Springer Nature	6

[a] This table shows the top 21 sources title publishing on computer science education

Table 3
Top publishing authors and institutions on computer science education

Author	Affiliation	TP	TC	Organisation	TP	TC
Hazzan, O.	Israel Institute of Technology	13	133	The University of Texas at Austin	15	332
Zendler, A.	Ludwigsburg University of Education	11	89	Georgia Institute of Technology	14	207
Hubwieser, P.	Technical University of Munich	10	245	Israel Institute of Technology	14	133
Repenning, A.	University of Applied Sciences and Arts Northwestern	9	180	University of Colorado Boulder	11	540
Diethelm, I.	University of Oldenburg	8	114	University of Oldenburg	11	304
Guzdial, M.	University of Michigan	8	174	Weizmann Institute of Science	11	389

Author	Affiliation	TP	TC	Organisation	TP	TC
				Israel		
Almstrum, V.L.	The University of Texas at Austin	7	28	Technical University of Munich	10	245
Ben-Ari, M.	Weizmann Institute of Science	6	310	Carnegie Mellon University	10	93
Giannakos, M.N.	Norwegian University of Science and Technology	6	272	Virginia Polytechnic Institute and State University	9	233
Klaudt, D.	Ludwigsburg University of Education	6	51	Aalto University	9	363

[a] Note: TP = total publications and TC = total citation

Bibliometric Network Analysis

Co-authorship authors network

From 1970 until 2021, 1461 authors published on CSE as co-authors. In Figure 3, 619 authors were graphically mapped based on at least one published work and five citations per author. In Figure 3, the authors' collaboration linkages are represented by lines and their collaboration clusters by 13 colours. Although the top ten authors in Table 3 are from different clusters, their strong connections show a significant research link connecting to CSE subjects. As illustrated in Figure 3, Hazzan, O. (cyan), Hubwieser, P. and Diethelm, I. (green), Guzdial, M. (brown), Almstrum, V.L. (yellow green), Giannakos, M.N. (orange) are all closely related.

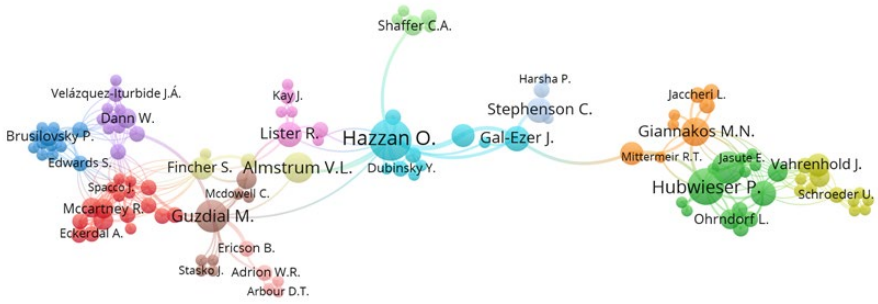

Figure 3: Network visualisation map of the co-authorship

Note: Unit of analysis = Authors; Counting method: Fractional counting; Minimum number of documents of an author = 1; Minimum number of citations of an author = 5

Co-authorship countries network

From 1970 to 2021, 112 countries published on CSE as co-authors. Using a threshold of at least three publications per country with 5 citations, 37 countries were chosen and classified into ten groups (Figure 4). Table 1 shows the United States leading in total link strength, documents, and citations. Despite their significant contribution in documents and citations, authors from Israel and Germany do not rank highest in the co-authorship network map of countries (Figure 4). This could be explained by intense intra-national research without much international collaboration. Moreover, the results of this work revealed a shift in the geographical distribution of CSE research publications, with the USA surpassing Germany in the network visualisation maps of international collaboration. While numerous institutes in the US are actively researching this topic, Germany remains prominent, where most of the prolific authors come from.

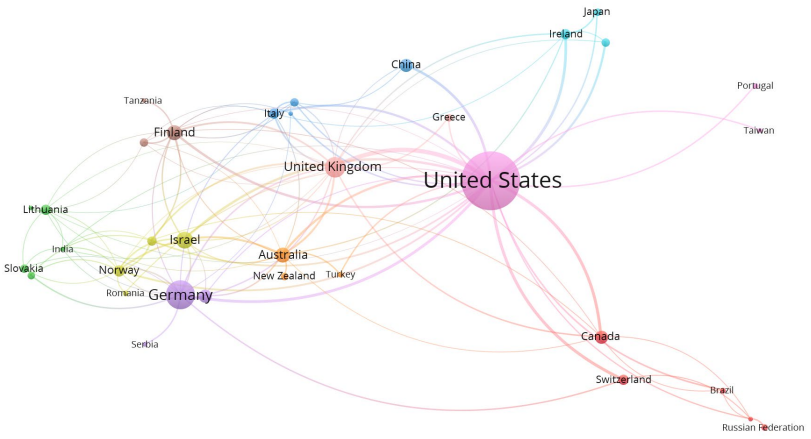

Figure 4: *Network visualisation map of the co-authorship.*
Note: Unit of analysis = Countries; Counting method: Fractional counting; Minimum number of documents of a country = 3; Minimum number of citations of a country = 5

Topical trends in the computer science education knowledge base

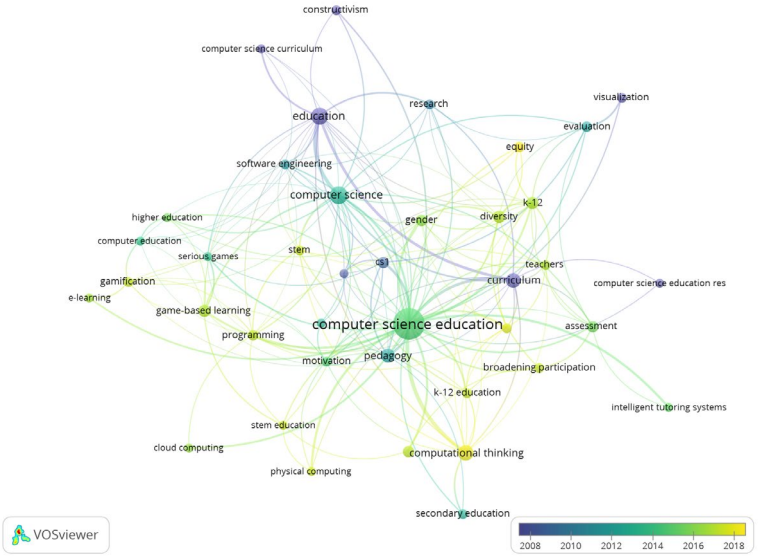

Figure 5: Overlay visualisation map of the co-occurrence.
Note: Unit of analysis = Author keywords; Counting method: Fractional counting; Minimum number of occurrences of a keyword = 5; Minimum number of cluster size = 7

In Figure 5, the co-word map has a temporal overlay that connects keywords to document dates. Temporal co-word analysis displays a topic's popularity peak (Agbo et al., 2021). Darker nodes represent topics that were popular earlier in this literature, and lighter nodes represent recent literature. This way, the evolution of CSE literature over the last 50 years may be followed using colour/shade analysis. The hot topics of temporal co-word map include computer science education (177 co-occurrences) and computer science (34 co-occurrences). STEM and computer science education are becoming increasingly inextricably linked. Computing education has emerged to facilitate the integration of stem education processes (Wing, 2006). Coordination in curriculum design and implementation of computer science education can benefit from "programming" and "stem education" collaboration (Taki & Alnahhas, 2019), "software engineering" (Summet & Bates, 2020), and "gamification" (Gari & Radermacher, 2018).

CONCLUSION AND SUMMARY

United States was the largest contributor to CSE research, followed by Germany. ACM SIGCSE Bulletin remained the main publication related to CSE research. The University of Texas at Austin, United States, is expected to be a good candidate for collaborative research in this field. The curriculum design and implementation, as well as learning and teaching research, could be the research subject areas to follow in years to come. This study will be of great important to funders, practitioners, and educational administrators as part of the strengths and weakness of the current computer science education research, in which the aforementioned knowledge can be used to make decisions on policy or practice.

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